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A machine-vision inspection system for conveying attitudes of columnar objects in packing processes

Liang Xu [a,*], Xiaomin He [a], Xiuxi Li [b], Ming Pan [c,*]

[a] School of Automation, Guangdong University of Technology, GuangZhou 510006, PR China
[b] School of Chemistry and Chemical Engineering, South China University of Technology, GuangZhou 510640, PR China
[c] Department of Chemical Engineering and Biotechnology, University of Cambridge, New Museums Site, Pembroke Street, Cambridge CB2 3RA, UK

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ABSTRACT

This paper is a new study on developing a machine vision system for inspecting the conveying attitudes of columnar objects. The presented system consists of image pre-processing, feature extraction, and attitude diagnosis. First of all, in order to segment the objects from the background (namely image pre-processing), an improved maximum between-class variance method is proposed for searching a histogram peak and calculating a threshold value based on the statistics and probability, to solve the problems caused by the non-uniform brightness in a realistic conveyor belt. Then, an open morphological operation is used to eliminate the noise from the binary images produced in the pre-processing step. In the second step (feature extraction), the features of columnar objects are determined by four methods, edge line detecting method, intercepting method, rectangle locating method and feature statistic method. Finally, the diagnosis for the conveying attitudes of columnar objects is based on a hybrid classifier using random forests, and a fuzzy logic. The proposed system is applied to a realistic process for packing industrial explosives. The results of experiments show that the proposed system allows efficient and accurate 100% inspection for the conveying attitude, which ensures the high speed and steady operation of a packing line.

1. Introduction

A packing process of columnar objects, for example, industrial cartridge explosives, candles, and sausages usually consists of a series of sub-units (sub-process), which working together tend to complicate the packing process. Inspecting the conveying attitudes of columnar objects is a typical task in the packing process. When the conveying attitudes of objects, defined as the position and the status of objects on the process, are in abnormal situations, the reliability and efficiency of a packing line will degrade. This causes an increasing demand for automatic inspection system for detecting the conveying attitudes of objects, where machine vision plays an important role.

In many studies, machine vision has been widely used in industry, and reported as an excellent tool for many inspection tasks. These inspection systems using machine vision for surface defect, appearance, shape, etc, of different objects appearing in various fields have been developed for many applications, e.g.

- A machine vision-based inspection system for electric contact (EC) [1].
- A machine vision system for inspecting metal ball defect defects [2].
- A system for the calibration of digital thermometers [3].

* Corresponding authors.
E-mail addresses: celiangxu@gdut.edu.cn (L. Xu), mp748@cam.ac.uk (M. Pan).

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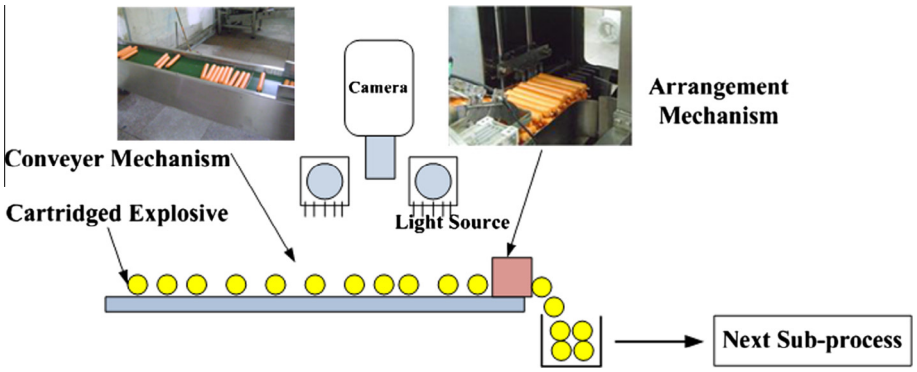

Fig. 1. A typical packing process for industrial cartridged explosives.

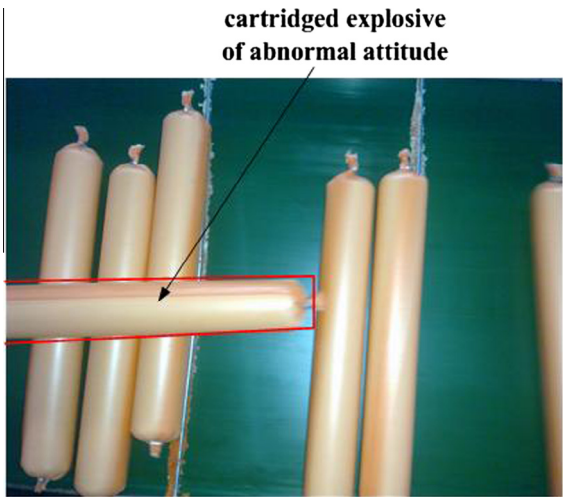

Fig. 2. A sample image for columnar objects from a real industrial process.

- An automated design validation of a vehicle instrument cluster [4].
- A vision-based system for automatic date quality evaluation for commercial production [5].
- High-accuracy calibration of micrometers [6].
- Detecting tiny flaws of the domed surfaces of LED epoxy-packing [7].

Recently, a variety of vision-based inspection methods have attracted numerous researchers. These methods in these studies include: a machine vision inspection method for measuring amplitude vibration based on image motion blur [8], regression and artificial neural network techniques used for machine vision calibration [9], and weeds identification using machine vision [10]. Some approaches, e.g. the Bayesian approach, artificial neural network [11], and support vector machines [12–14], are applied as classifiers for the development of a machine vision system.

In a machine-based inspection method, classification is an important procedure, and much effort has been invested in the development of many methods. These methods include: Decision tree [15–17], Random forests [18,19], Rough set theory [20,21], Fuzzy logic [22,23], Neural Network [24,25], Support vector machines [26,27].

Random forests (RF) and fuzzy logic provide two different approaches that can be used for classifying normal and abnormal situations according to the amount of feature information on the conveying attitudes of columnar objects. RF, i.e. a classifier combining a forest of decision trees grown on random input vectors and splitting nodes on a random subset of features, have been introduced for the classification of binary and multiclass outputs [18]. RF inherits decision tree capacity to cope with huge feature spaces but eliminates its instability disadvantage. In terms of robustness to outliers and noise, and calculation time, RF is superior to other machine learning methods such as bagging or boosting. However, only a few implementations of random forests have been applied successfully in solving an image multiclass problem.

The fuzzy logic approach is usually used for a classification problem that is too complex to be analyzed by the conventional means. Moreover, it transforms subjective knowledge (linguistic information) and qualitative evaluation into numerical measurement. The essence of fuzzy logic lies in its ability to handle linguistic information by representing it as a fuzzy set. Other aspects worth examining when comparing fuzzy control with conventional control are robustness and adaptive [28]. Fuzzy logic has been applied to many interesting problems in different fields including seeds germination quality valuation [22], noise identification/recognition [23], qualitative safety modeling for marine system [29], diagnosis of hypothyroidism [30], etc.

As mentioned above, the machine-vision detection methods completely depend on the different inspecting objects and real industrial processes, however, no existing work has been published for identifying the conveying attitudes of columnar objects in industry. In this paper, an efficient machine-vision inspection approach incorporating a serial of the methods and a system is developed for detecting and recognizing various normal and abnormal situations of columnar objects in a packing process. In image pre-processing step, a calculating model is proposed for segmenting the objects from the background. Secondly, the features of columnar objects are identified with four methods, which are based on image processing technology